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ABSTRACT

This unit, developed by the Third World Science Project, is designed to add a multicultural element to existing science syllabi (for students aged 11-16) in the United Kingdom. The project seeks to develop an appreciation of the: boundless fascination of the natural world; knowledge, skills, and expertise possessed by men/women everywhere; application of knowledge and skills to solve the practical problems of everyday life; impact of modern technology in the world; and the influence of the cultural background on the perception of knowledge, problems, and solutions. The unit (which assumes students have previously been introduced to energy and its different forms) focuses on different types of energy convertors which can be related to the Third World. The introduction explains how unconventional energy courses may help Third World countries to improve their agricultural methods and living standards, proceeding with discussions of energy sources, importance of photosynthesis/plants, raising of water by muscle power, and other devices which make use of muscle power. Other types of energy convertors widely used in underdeveloped countries are the described, including water wheels, wind energy, and solar energy. The unit concludes with list of addresses to obtain detailed information to construct energy converts in the school laboratory. (JN)

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# ENERGY CONVERTORS

SE043331

# THIRD WORLD SCIENCE

Third World Science seeks to develop an appreciation of:

1 The boundless fascination of the natural world

2 The knowledge, skills and expertise possessed by men and women everywhere

3 The application of knowledge, skills and expertise to solve the practical problems of everyday life

4 The impact of modern technology in the third world

5 The influence of the cultural background on the perception of knowledge, problems and solutions

The following Units have been designed to fit into existing science syllabuses in the United Kingdom:

CARRYING LOADS ON HEADS: CHARCOAL: CLAY POTS:
DENTAL CARE: DISTILLATION: ENERGY CONVERTORS:
FERMENTATION: HOUSING: IRON SMELTING: METHANE DIGESTORS:
NATURAL DYES: PLANTS AND MEDICINES: SALT: SOAP.

The method of use is not closely prescribed. As resources teachers may use them in different ways though suggestions are offered. Feedback is invited from teachers concerning (a) the use made of the material (b) pupils reactions, if possible in their own words, and (c) suggestions for improvements, additions etc.

Please send feedback, ideas and requests to:

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# ENERGY CONVERTORS

## Teacher's Notes

In this unit are outlined different types of energy convertors which can be related to the Third World, as most of them make use of natural and easily available forms of energy, and the devices are generally inexpensive and easy to operate. It is assumed that the pupils have already been introduced to energy and its different forms. The unit demonstrates how simple energy converting machines can help in raising living standards.

The introduction explains how unconventional energy sources may help Third World countries to improve their agricultural methods and standard ofliving.

The unit proceeds with a short explanation of where we obtain our energy, and the importance of photosynthesis and plants, and this is followed by a section on the raising of water by muscle power, showing very simple methods, but ones which are very important to the farmer in irrigating his land. There are also other devices described which make use of muscle power.

Many other different types of energy convertors are described which are used widely in underdeveloped countries, which utilise natural resources. At the end of the unit there is a list of addresses from where more detailed information can be obtained to construct an energy convertor in the school laboratory.

# ENERGY CONVERTORS

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# INTRODUCTION

Energy is required, by definition, to do any kind of work; the rate at which it is used is measured as power. We can do a certain amount of work slowly (using little power) or quickly (using more power) - involving the use of a similar amount of energy in either case. Almost all human activities require work to be done; ploughing fields, lifting water, transporting ourselves, mining for minerals, manufacturing, cooking food, and so on. The method used depends on the power available, the form needed (i.e. as heat, shaft power, electricity, pressurised water on air, etc.) and its cost.

The last factor of cost, limits most people in the underdeveloped parts of the world to using their own muscle power or that of their domestic animals. Artificial power sources we take for granted in developed countries, such as mains electricity (originating in the main from coal and oil), petrol engines, and diesel engines are often too expensive for most people to buy or run. Increasing fuel costs caused by a growing oil shortage will make artificial oil burning power sources even more expensive. Yet without artificial power sources the poor will be unable to improve their agricultural methods and imorove their standard of living. Therefore there is now a lot of interest in unconventional alternative energy sources which are often said to be 'free', such as wind, rivers, and heat and light from the sun.

No energy is free - it always costs money to convert it into a useable form. A windmill may cost little or nothing to run, but the materials and labour used in its construction need to be paid for. And as the wind is a much weaker energy source than petrol, a windmill of a given power output is likely to be much larger and consequently more expensive to manufacture than a petrol engine of the same power. Similarly, solar water heaters cost more than electric immersion heaters to buy in the first place, but they obviously cost little or nothing to run, whereas electricity is expensive. So a lot of work is in hand to find ways of building low cost solar and wind powered devices which might be used in underdeveloped parts of the world. One of the most important requirements to allow more land to be usefully cultivated is the provision of irrigation water. So, much current effort is concerned with finding methods for pumping water onto the fields.

## WHERE DOES ENERGY COME FROM?

If you asked where did all the energy come from in the universe to start with, the answer would be "No-one really knows". But we do know where all the energy which we use on the earth comes from.

At some time over the past hundreds of millions of years, the country was under the sea, then a sandy desert, perhaps part of a lava field from a volcano, maybe a swamp and possibly even covered by a thick sheet of ice. During all this time the sun was pouring energy into our planet from 90 million miles away.

Scientists calculated that the sun will continue to supply us with energy for a thousand million years or so into the future. The energy from the sun travels to us in waves, and it takes about eight minutes twenty seconds to reach us.

One of the effects of heat and light energy was that, about two hundred and fifty million years ago, dense tropical forests were able to grow at some places on the earth, including the area around the South Pole.

At other times the heat and light allowed tiny plants to grow here, on which animals fed. Nowadays we find the remains of these organisms turned into oil or natural gas. When we burn any of these fuels which in the distant past were in the form of some kind of plant, it is just as if the heat we get from them today is the heat and light energy they obtained from the sun and locked up within themselves when they were growing.

## SYNTHESIS FROM SUNSHINE

Of all the compounds that exist in nature, by far the most important as sources of chemical energy are those containing carbon. All the important fuels, coal, oil, gas, wood, alcohol - contain carbon, as do all the principal foods - sugars, starches, proteins, fats. All fuels and foods are the products of once living things - the carcass, the by-products, the decayed bodies of plants and animals. It is because all fuels and foods are the end products of plants, the primary storehouses of chemical energy of the sun. This transformation in plants takes place in the remarkable chemical process know as photosynthesis, which uses water and carbon dioxide as raw materials. The water is absorbed from the soil through the roots, the carbon dioxide from the air through the leaves. The plant then proceeds to split the water molecule and splices hydrogen into carbon dioxide to form a new molecule containing carbon, hydrogen and oxygen, a so-called carbohydrate molecule is converted to one of the most common carbohydrates of all; sugar.

The inescapable *First Law of Thermodynamics* tells us that the energy required to break up a molecule is equal to the energy obtained when the molecule is put back together again. When we eat carbohydrates and burn them in our bodies, we are putting the water molecule back together, and the energy we get from foods is the product of this reunion.

This energy can then be used in different ways, most of it used for doing work i.e. walking, lifting, pushing.

*The First Law of Thermodynamics can be stated:
Heat can be converted to and from other forms of energy. In the process energy neither created or destroyed.*

## MAIN CLASSES OF ENERGY CONVERTORS

### HEAT

Direct Burning (wood, coal, oil, gas)

Solar flat plate - water heating
- air heating
- distillation

### MUSCLE POWER

Human and Animal

### INTERNAL COMBUSTION ENGINE

(oil, gas)

Reciprocating - Petrol-spark ignition
Diesel compression ignition
Humphrey water piston

Rotary - Gas turbine

### HEAT ENGINES

(Any source of heat, solar, oil, gas, coal, wood)

### ELECTROMAGNETIC RADIATION

(solar energy)

Photocells

### HYDRAULIC ENGINES

(water power)

wheels, screws, buckets, turbines

### WIND ENGINES

(wind power)

wind mills - horizontal axis, vertical axis

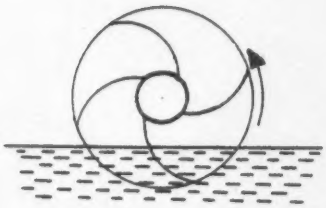
### ELECTRICAL/MECHANICAL

Dynamo/Alternator (mechanical shaft power)
Motor (electricity supply)

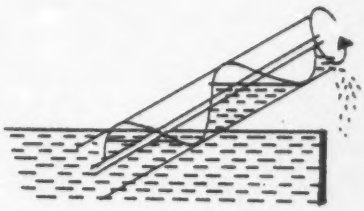
# RAISING WATER USING MUSCLE POWER

A large part of the underdeveloped world lies in the tropics. This means that they get very little rainfall or sporadic rainfall. The people who live in these areas depend on agriculture for their living where water is very important. To water large tracts of land the farmer has to carry water from a nearby river. To do this more easily he usually lifts the water and pours it into narrow channels which then carry the water to the point where it is needed. This is called irrigation. It would take the farmer all his time if he had to lift the water using only a bucket. To help him raise more water quickly, many different methods have been devised over the centuries, and still in use today, which use muscle power more efficiently.

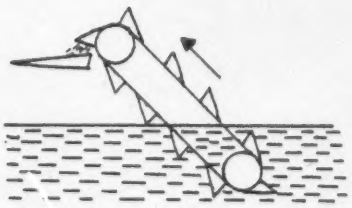
Shown are several different methods which show how muscle power, human or animal can be used to raise the energy level of the water.



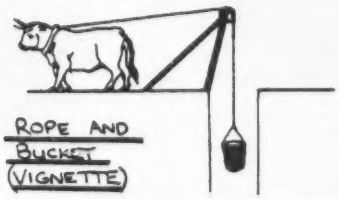
SAKIA.



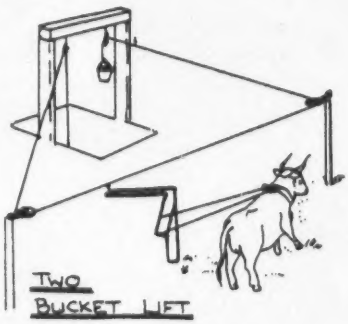
ARCHIMEDEAN SCREW PUMP



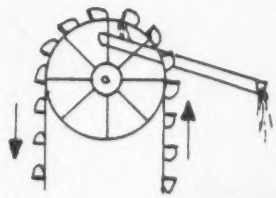
WATER LADDER (DRAGON'S SPINE)



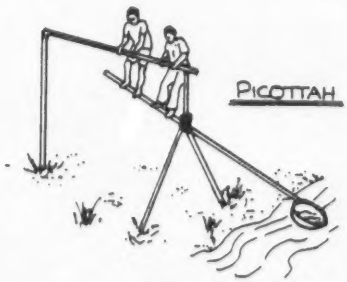
ROPE AND BUCKET (VIGNETTE)



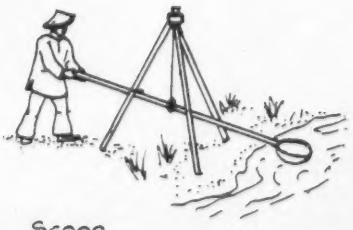
TWO BUCKET LIFT



PERSIAN WHEEL.

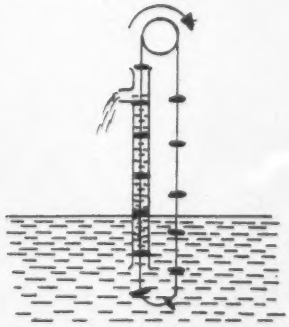


PICOTTAH



SCOOP

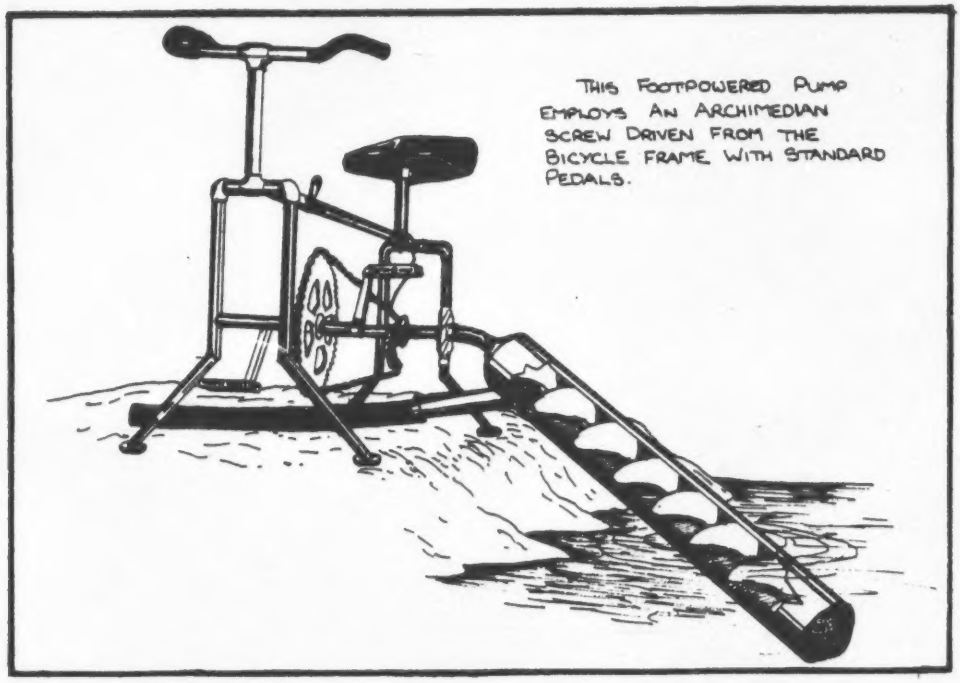
SHADUF.

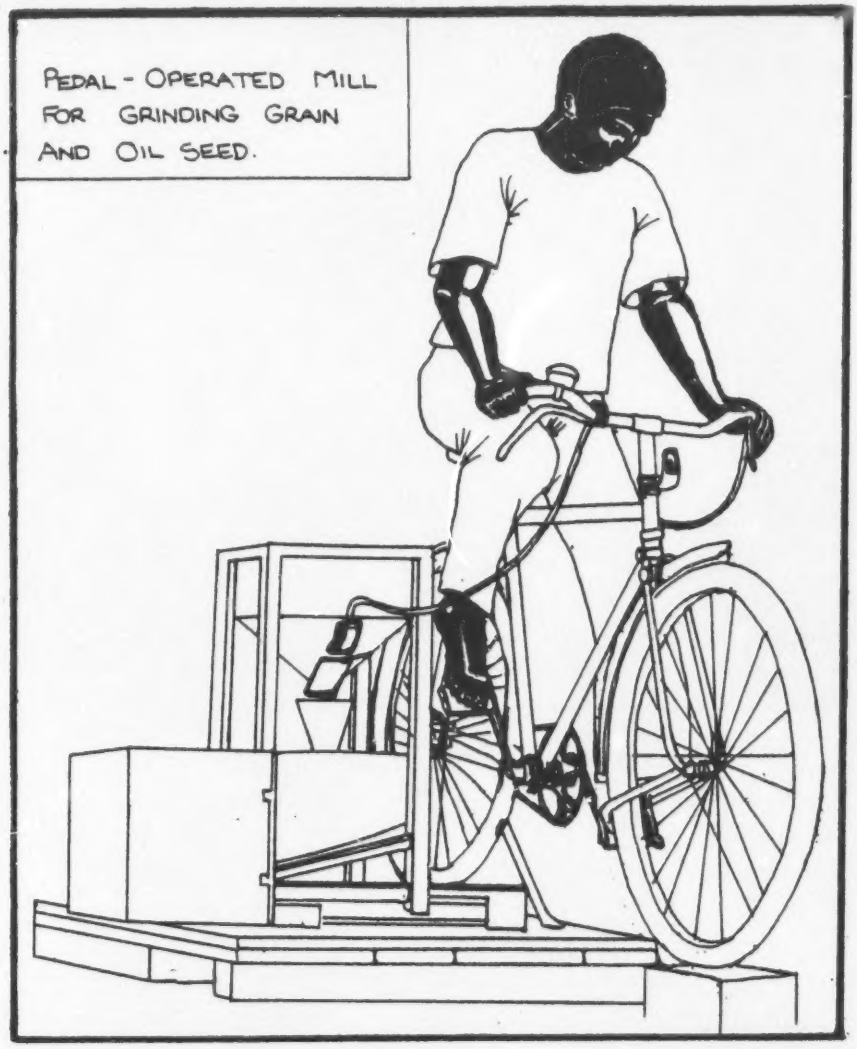


CHAIN AND DISC.

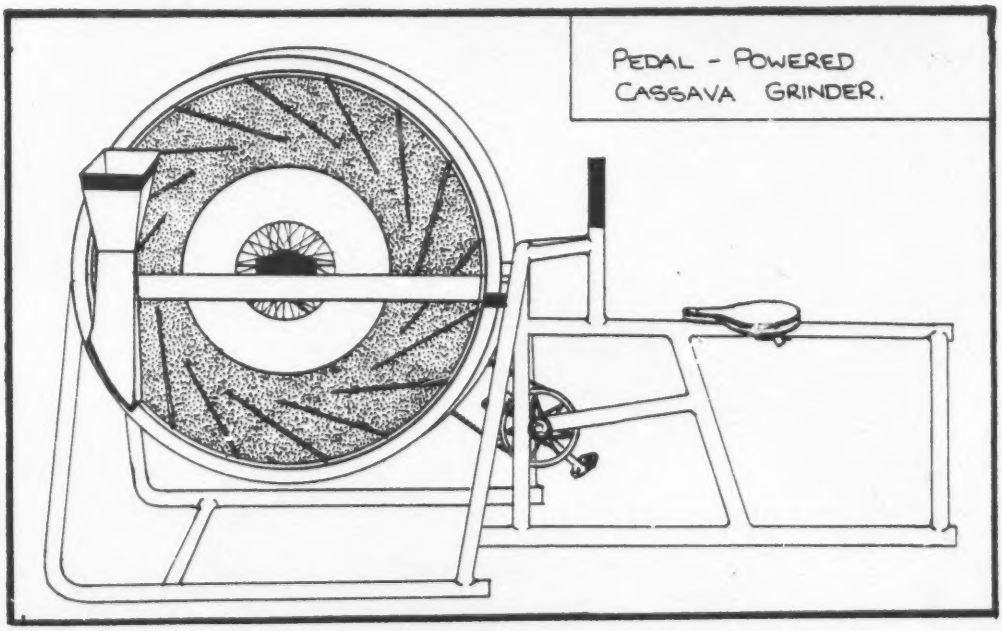
## Other devices which use muscle power

One of the most efficient methods of using human muscle power, is the bicycle, which provides a great deal of the transport in many developing countries, particularly the Far East. The normal cyclist can develop about 220 watts for a sustained period. The bicycle power train - that is, the seat, pedals and chain drive, can be used for static purposes. A system has been developed under the name of Dynapod where the bicycle can be used for a number of crop producing applications such as winnowing grain. The cassava grinder from Nigeria uses the same principle. Cassava is fed into the hopper and forced against hacksaw blades fixed into a bicycle wheel and moving across the hopper outlet. A similar arrangement can be used to power a simple wood working lathe. The fly wheel is made from a bicycle wheel which is filled with concrete in order to increase the interior of the flywheel, that is, enable it to store more energy.





PEDAL - OPERATED MILL FOR GRINDING GRAIN AND OIL SEED.



PEDAL - POWERED CASSAVA GRINDER.

## OTHER METHODS OF RAISING WATER

Muscle power is the cheapest way of raising water but it is also the slowest. To use other forms of energy to raise water involves greater cost but it would mean that the farmer and his animals could be put to better use.

The kinetic energy of the wind has been used for many years to raise water not only for irrigation but also for draining land such as in Holland.

The wind is a large source of energy, but to capture this energy, large sails have to be constructed. The straight line (linear) motion of the wind can be changed into rotational movement by the sails turning. The windmill not only changes the direction of the energy but also concentrates the energy into a shaft which can be used to turn a pump. Of course the major problem with the windmill is that you must have wind.

Another method of raising water is to use the hydraulic ram which utilises the flow of water in a stream to raise water to a much higher level, described later in the text.

A few farmers use petrol or diesel engines to pump their water. This is very costly but much more quickly which means that the farmer can irrigate a much greater area of land but, as usually what happens in a majority of cases, when the engine breaks down there is usually no part or a mechanic, which can repair the pump, so it lays idle for long periods of time.

A new method of pumping water using modern technology is being researched at the present time using the largest source of energy available to us, the sun. Following is an extract taken from the New Scientist which explains the possible use of photovoltaic cells in converting light from the sun into electrical energy for the pumps.

# TECHNOLOGY

## Solar pumps raise the level of agriculture in Pakistan

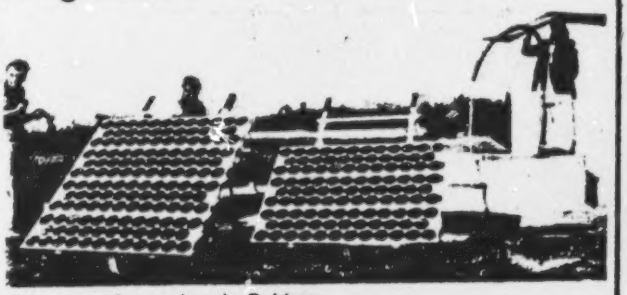
SOLAR-POWERED irrigation pumps could soon be a common sight in Pakistan's farmland. The country has begun national field trials so that farmers can compare solar pumps with diesel-powered irrigation equipment. In Pakistan alone, farmers could use up to 500 000 such pumps, so the field trials, arranged by Intermediate Technology Industrial Services (ITIS) of Rugby—part of the Intermediate Technology Development Group—are attracting a lot of interest from both the Pakistani government and equipment manufacturers.

Companies taking part in the trials include Solar Electric International (SEI) of the US and Lucas Energy Systems of the UK. ITIS is providing funds for the trials in cooperation with Lucas and SEI, and with KSB of West Germany whose pump draws power from 18 of SEI's solar arrays.

An irrigation engineer working for ITIS has recently returned from a two-month trip to Pakistan during which he arranged siting, preliminary testing and "open days" for farmers to inspect the equipment, in conjunction with the Agricultural Research Council and Agricultural Development Bank of Pakistan. During the next nine months farmers will put the arrays to work growing summer and winter crops.

Although the solar arrays are comparatively dear at the moment, the manufacturers expect their price to fall from around $5000 to $1500 through mass production. John Frost, a project surveyor for ITIS, says: "We would expect the price of the Sun pump to converge with that of a diesel pump in five years, even though diesel pumps are getting cheaper."

David Wright, general manager of ITIS says: "The aim has been to work from the needs of the small farmer who has no access to a national electricity grid to find a product which will complement or replace his usual irrigation equipment. Who knows what a barrel of oil will cost in 20 years? We know what the Sun pump is going to cost throughout its life."



*Solar pumping arrives in Pakistan*

About 44 per cent of Pakistan's farmers own between 1 and 3 hectares (2-7 acres) of land. It is this group that stands to benefit the most from a solar water pump that should need little maintenance, could be made locally, and would qualify for a government subsidy for diesel- and electric-powered equipment.

Power for pumps comes from photovoltaic cell panels. The cost of a cell for each watt it can produce has been dropping steadily: at one time it was $35 per watt, and is now about $12. The portable arrays can pump between 70 and 280 litres a minute of water from between 2 m and 5 m below ground, and have an anticipated life of 10 years for KSB's pump and 15 years for the solar panel.

This year, ITIS will study the effects of salt water and sand on the efficiency of the pumps, and of damage through careless handling. Graham Pallett, an irrigation engineer with the project, says that technical problems that have arisen so far include the failure of one of SEI's control panels because moisture had crept into it before it was installed. Because one of the Lucas pumps was incorrectly connected, its battery became discharged and no longer operated the motor to drive the pump's mechanism.

Pallett adds: "Farmers are going to need training to improve their irrigation infrastructure. The Sun pump runs throughout the day at low flow. In contrast, diesel- or mains-electric pumps operate at high output for several hours. Conventional pumps also lose a lot of water because of labyrinthine unlined irrigation ditches. The problem will be worse with a Sun pump that produces a low flow of water. A first step to tackle this has been the provision of 100 metres of 8-cm, PVC pipe so that pumps can direct the water more carefully." In old, unlined wells the pumps caused the water level to fall by up to 2 m, so farmers drew less towards the end of the day.

The farmers were so enthusiastic about the new technology that several dug new, masonry-lined wells. One young farmer with 5 hectares of land has been able to completely replace his animal-driven Persian wheel pump with a Sun pump which he is now testing. □

## THE HYDRAULIC RAM

The hydraulic ram is a pumping device which utilizes a small fall in a natural stream to pump a fraction of the flow to a greater height.

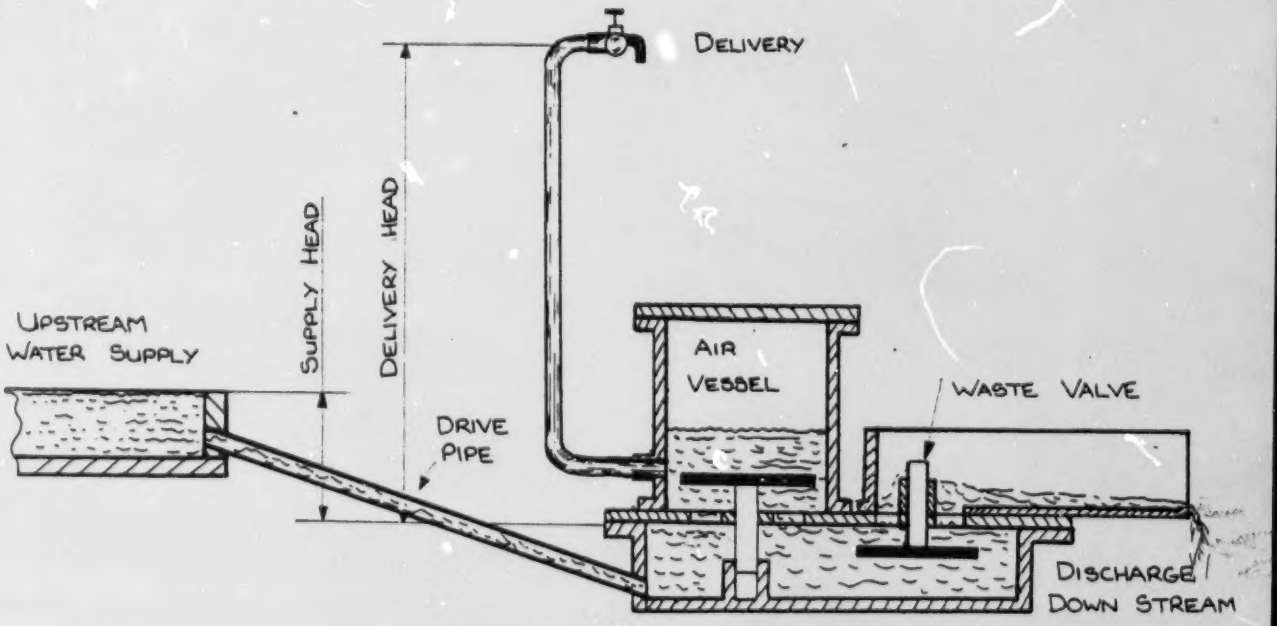
The simplest form of ram is shown diagramatically below

Water flows down the pipe to the valve box, and initially returns to the stream through the waste valve. As the flow accelerates there comes a time when the hydraulic drag on this valve overcomes its weight and begins to close it against gravity. When once the movement starts, the action is cumulative and the valve closes with a characteristic thud.

The sudden change in the flow down the drive pipe leads to a rise in the pressure in the valve box sufficient to open the delivery valve and to cause some water to flow up into the air vessel and them to delivery. When the momentum of the flow in the drive pipe is expanded the delivery pressure, augmented by the elasticity of the water and of the pipes, initiates a reverse flow. This promptly closes the delivery valve. The waste valve then falls open, so re-setting the ram for the next cycle.

Rams have been used widely in rural areas for the supply of water to houses and farms and, in some areas, to whole village communities.

Rams can be made which will operate with head as low as 10 cm but usually a head upwards of 1 metre is used and the delivery head may well be twenty times as great.



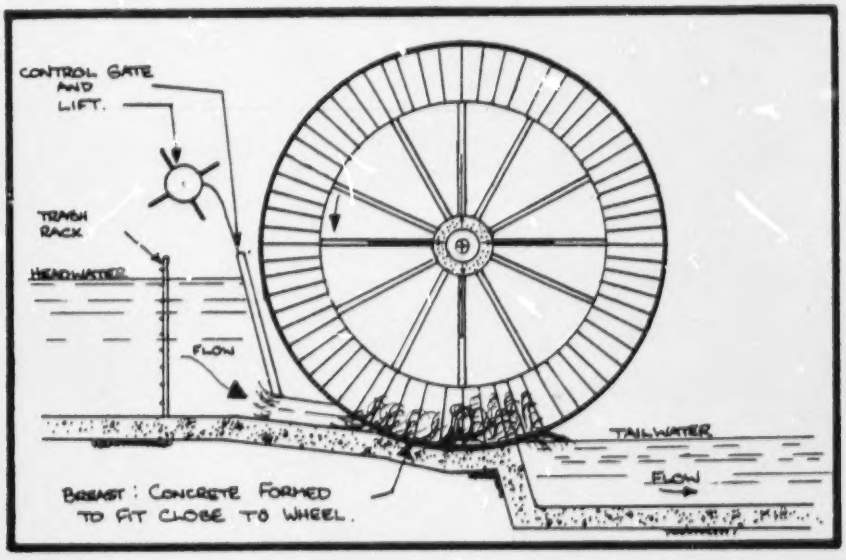

HYDRAULIC RAM.

## WATERWHEELS

Water wheels are particulary useful for generating mechanical power. This power is taken off the centre shaft of the wheel and is usually connected via belts and pulleys to machinery. Waterwheels generally operate at between 2 and 12 revolutions per minute (r.p.m.) and are appropriate for slow speed applications such as turning grinding tools, pumping water and running light machinery and tools (e.g. lathes, drills, presses and saws). Water wheels may be used to generate electric power but because of the slow rotational speeds, difficulties are often encountered. Water wheels will operate in situations where there are large fluctuations in the flow rate, but the changing flow will bring about a change in the r.p.m. of the wheel.

## UNDERSHOT WHEEL

The most basic design in water wheels is the old-style under shot wheel. The earliest design for the undershot wheel was a simple paddle wheel, immersed in the stream flow that splashed along with the current.




THE UNDERSHOT WHEEL.

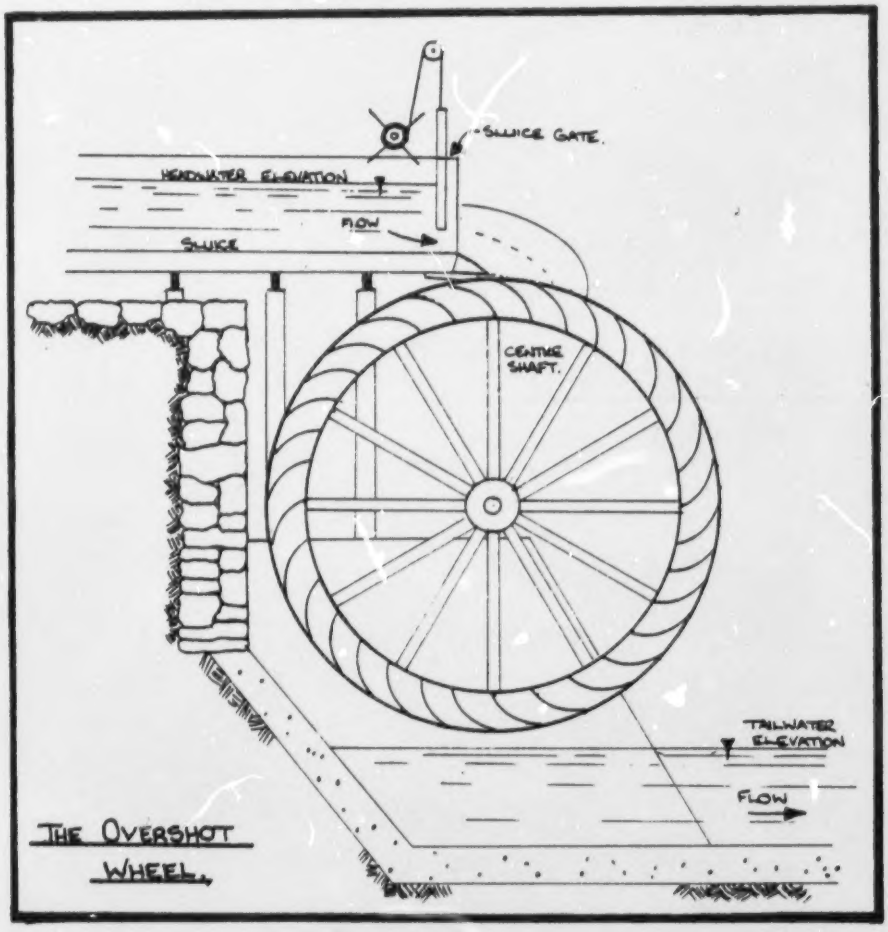
The refinements that were developed to improve the efficiency of the undershot wheel included better controls of the water in order to increase the velocity of the water as it hits the paddles and to limit the amount of water so the paddle could not get bogged down in the backwater.

The Poncelet wheel is similar to the undershot wheel except that the blades are curved which allows the water to enter the buckets with a minimum of shock.

## OVERSHOT WHEEL

Overshot wheels have traditionally been used for falls (heads) of 3 to 10 metres. In an overshot wheel, a small portion of the power is a result of the impact of the water as it enters the bucket. Most of the power is from the weight of the water as it descends on the buckets.

The wheel will still operate when the supply of water is small but at a much reduced power. The supply of water is regulated by a sluice gate which in most cases is regulated by hand, although it could be regulated by an automatic governor.

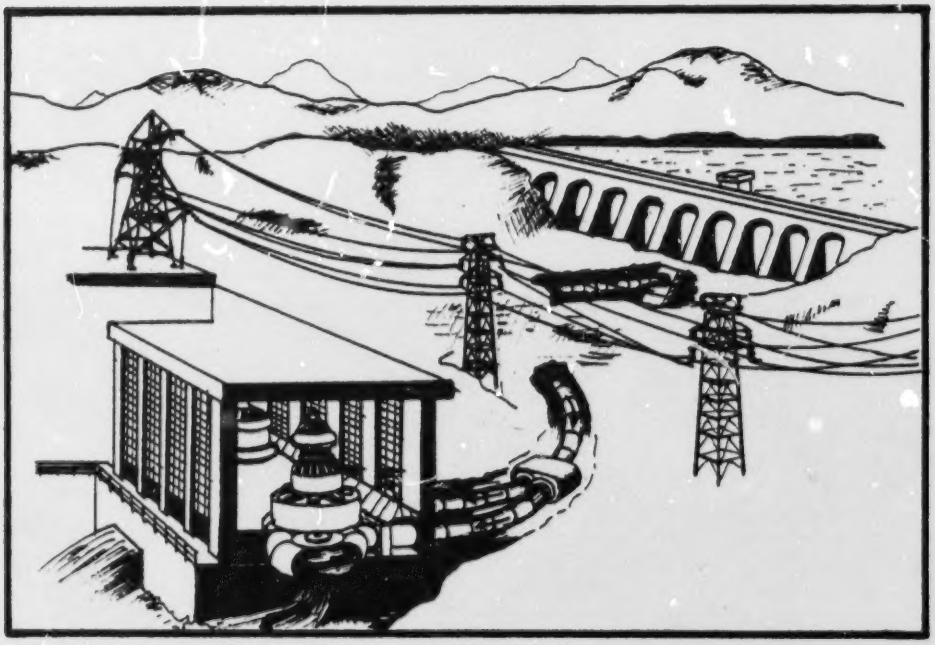



## WATER TURBINES

Water turbines are used for producing either direct current (D.C) or alternating current (A.C.). Large amounts of electricity can be produced in this way. Many large hydro-electric schemes have been built around the world such as the Aswan Dam in Egypt.

In most hydro-electric power stations the water is stored in a dam at a high level, the height the water falls to reach the power station is known as the 'head': the greater the head the faster the flow. A combination

of flow rate and the head determines the amount of power which can be gained from a river. Several types of turbine are used in power stations. The



choice depends on the height of the head. For very high heads of water the usual choice is the *Pelton Wheel*. This turbine has a slight resemblance to the overshot water wheel.

The Pelton Wheel has a ring of cups around its edge, with their open sides facing around the edge of the wheel. Water squirts through a narrow nozzle set tangentially to the edge of the wheel so that the jet strikes each cup in turn on its concave face. Because the Pelton Wheel is turned by the impact of the water jet is called an *impulse turbine*. There is another type of impulse turbine called a *turbo-impulse* in which the jet is parallel to the axle of the wheel and strikes a ring of angled blades.

Impulse turbines are only suitable for high heads and fast flows. Medium and low heads demand another design classed as *reaction turbines*, these have blades immersed in water and are turned by water pressure, this pressure being the product of the height of the head above it.

All hydro-electric power stations are coupled directly to alternators to generate electricity.

## BASIC PHYSICS OF WIND ENERGY

Wind is simply molecules of air moving at speed. When they hit the sails of a windmill they lose their momentum and they slow down. Because momentum can never actually disappear it is instead taken up by the windmill, and around it goes. The molecules cannot actually transfer *all* their momentum to the windmill; they have to retain some of their motion in order to make way for other molecules. It has been shown that the maximum fraction of the wind's energy which can be converted by a windmill is 16/27 or 0.593. This figure is known as the *Betz coefficient.*

The longer the windmill the more the power it will produce. In fact, what is really important is the *swept area,* since this determined the number of molecules which will crash into the sails and make them turn around. Because the area of a circle is proportional to the *square* of the diameter (i.e. $A = \frac{\pi d^2}{4}$ ) this means that if you double the length of your blade, the power output will increase *four times.* (For example, a 2 m blade has swept an area of 12.56 $m^2$)

Similarly, the power output is proportional to the *cube* of the wind velocity. So if the windspeed doubles, the power output will increase *eightfold.*

No machine is 100% efficient, a lot of the windpower which goes into the windmill will have to overcome friction and will therefore be lost as useless heat, or, even worse be 'used' to grind tiny bits of metal off the bearings. Every machine has what is known as a *power coefficient;* which is an indicator of how efficient it is. The power coefficient is the ratio of the power which comes out of the windmill into the power which goes in. A typical figure for a windmill would be 0.45, which means 55% of its energy is wasted in one form or another. To get a rough idea of how much power your windmill will give out, you need to know the swept area (A), the wind velocity (V), the power coefficient (C), and of the Betz coefficient. You substitute those values in the equation:

$$P = 0.593 \times C \times A \times V^3$$

(Since the Betz coefficient does not change its been put in already)

If you measure area in square metres and speed in metres per second, and you want your answer in a convenient unit, such as kilowatts, then you have to multiply your calculation by 0.00064

For example, a 45% efficient windmill with a 2 metre blade, running in a 4 metres per second wind will give:

$$P = 0.00064 \times 0.593 \times 0.45 \times 3.14 \times (4)^3 = 0.0771 \text{ kW}$$

## WIND

Wind is a form of energy created by the sun, the heating of the atmosphere during the day and its absence, cooling the night sky. Heat causes low pressure areas and the lack of heat results in high pressure areas. This process causes the wind.

## WINDMILLS

The energy of the wind is used to rotate large sails or blades. This converts the erratic energy of the wind into a more compact and useable form via a shaft to operate different devices.

## WIND PUMPING WINDMILLS

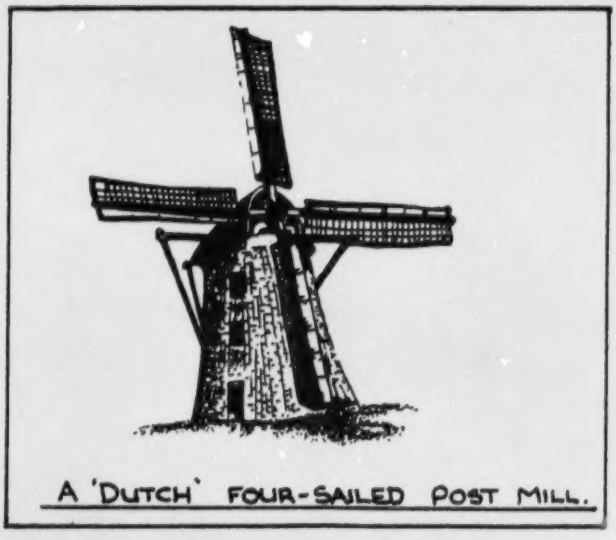
The rotating shaft is used to operate a pump which lifts water from a low level to a higher level thus increasing its potential enegy. One way of using this water which has gained energy is to use it for irrigation.

## MILLWRIGHTING

This type of windmill is the same as the one used for water pumping only larger, as greater power is required to turn a heavy grinding stone (diagram).

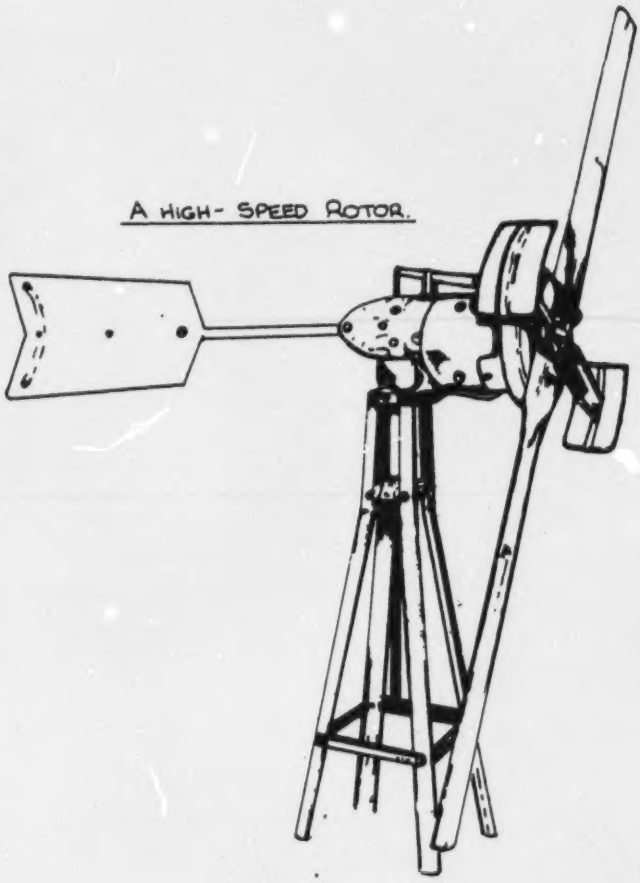
## WIND DRIVEN GENERATORS

The wind driven generator is a much smaller windmill and is designed to rotate very fast and it is this speed of rotation which determines how much elecricity can be produced via a generator. Electrical energy is much preferred to the mechanical energy in a shaft as it is easier to handle electricity over large distances and is easier to convert to other forms such as light and heat.



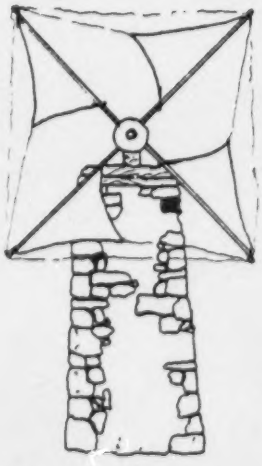
A 'DUTCH' FOUR-SAILED POST MILL.

# TYPES OF WINDMILLS.

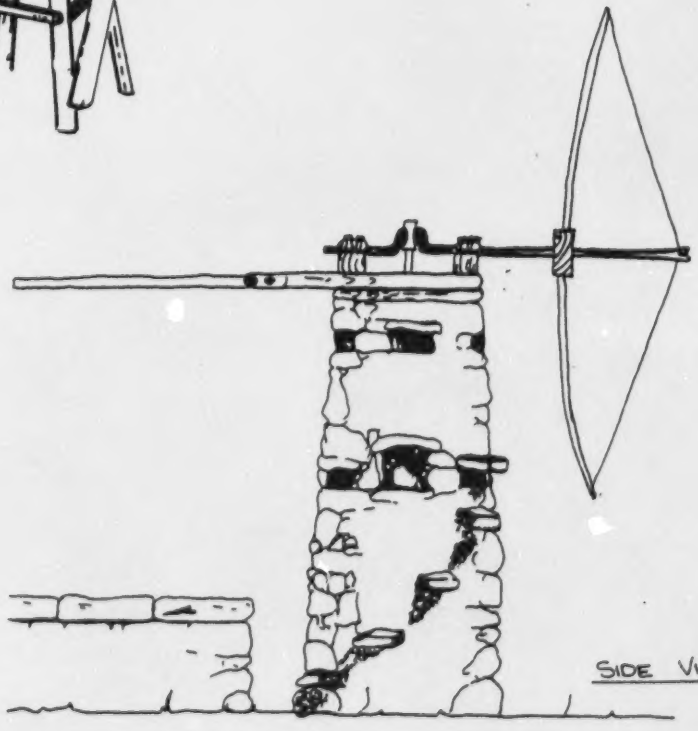


A HIGH-SPEED ROTOR.

AN 'AMERICAN' MULTI-BLADE FAN.



FRONT VIEW.



SIDE VIEW

AN IRRIGATION WHEEL ON STONE TOWER.

## SOLAR ENERGY

The sun is the basis of nearly all the energy available on our planet and is the largest source of energy if we could capture it. Its present rate of energy output is approximately $3.8 \times 10^{23}$ kilowatts, but only a very small amount reaches the earth and only a very small fraction of this is used. The biggest user of solar energy are plants which need it to produce food.

The sun is a huge massive nuclear reactor which produces energy by nuclear fusion., that is when two nuclei of hydrogen atoms unite together, under certain conditions, a resultant release of energy is given out. This energy is received by out planet mainly in the form of heat and light. This process has been occuring for millions of years and will continue for many more millions of years. So it makes sense for scientists to try and develop ways to use this free power. Below are outlined some devices which use the sun's energy either by concentrating the power or changing it.

## FUNDAMENTAL PRINCIPLES OF SOLAR ENERGY UTILIZATION

There are three primary processes by which the sun's radiation can be put to technical use: (1) Helio chemical, (2) Helio electrical and (3) Helio thermal. These are derived from the Greek word 'Helios' meaning "the sun". Other terms often used are: Helio static, referring to devices which are stationary with respect to the sun or which make the sun appear to stand still; helio tropic, referring to devices which follow or track the sun, and helio-chronometry, which means the telling of time by means of the sun.

## HELIOCHEMICAL

The most important helio chemical process is photosynthesis which enable certain wavelengths from the solar spectrum to cause carbon dioxide and water to unite with nutrients from the soil and thus create plants and oxygen by which we live. All of the coal, oil and natural gas that our planet has ever possessed has come from the same process. We are just beginning to understand photosynthesis, but even the greatest laboratory in the world cannot equal a single blade of grass or the leaf of a tree in bringing about this remarkable process.

Man has not yet made much use of the helio chemical processes, execpt perhaps in the field of photography.

## HELIO ELECTRICAL

Helio electrical processes are entirely man-made, since nature has not produced anything that converts solar radiation directly into useable electricity. These are also the most recent of the sun powered divices to make their appearance. Really significant helio electrical apparatus dates back only three decades to the invention of the silicon solar battery. Silicon solar cells utilize the ability of solar radiation to dislodge electrons from properly treated silicon and thus to cause an electric current to flow.

These were the first sun-powered devices to attain real and unqualified success; the exploration ot space and landing men on the moon would not have been possible without the array's of silicon cells which have powered virtually all our space vehicles.

## HELIO THERMAL

Helio thermal devices absorb solar radiation on blackened surfaces and convert it to heat. The black surface will attain a temperature at which equilibrium is established between the rate at which energy is being absorbed and the rate at which the absorbed energy is being lost to the surrounding atmosphere and put to useful service.

The blackened sheet of metal, heavily insulated on the side away from the sun and covered with a sheet of glass to trap the absorbed solar heat, may approach 150$^{o}$C. The heat absorbed by the metal may be carried away by water circulating through tubes attached to the metal plate, or by air blowing over the sun-heated metal. The glass cover plays a vital part by transmitting as much as 90 per cent of the solar radiation to the plate and by refusing to transmit back to the atmosphere the long wave radiation (heat) which is emitted by the plate. The glass also makes a major reduction in the amount of convective heat loss, i.e., the carrying away of heat by movement of the air at the surface of the plate.

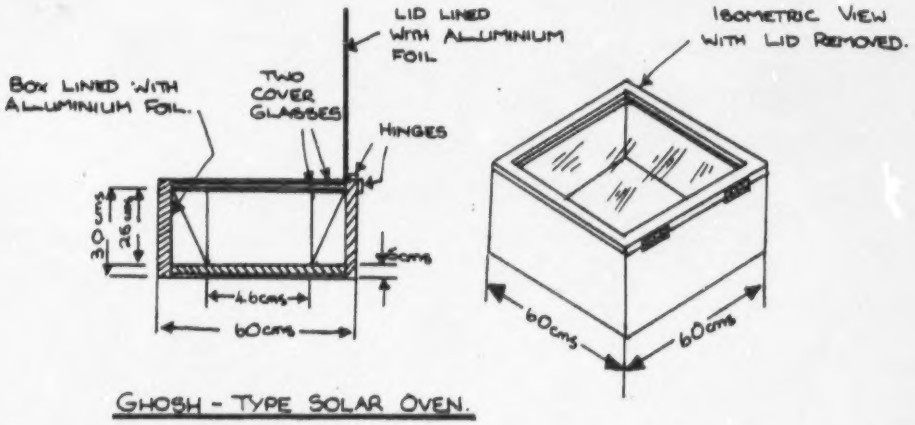
Helio thermal devices have been used with varying degrees of success for more than a century to produce temperatures ranging from below the freezing point of water to nearly 3300$^{o}$C.

## SOLAR OVENS

Cooking by the use of solar heat is a very old art. The first solar cooker was probably built in Bombay, India in 1880, and several other ingenious ovens have also originated from that country.

One of the best solar ovens was developed by Dr. M.K. Ghosh of Jamshedpur. The Ghosh heater consists of a simple wooden box about 60 cm square and 30 cm deep. This is lined with about 5 cm of insulation and then covered with shiny aluminium foil to reduce radiation from the oven to the sides and bottom of the box.

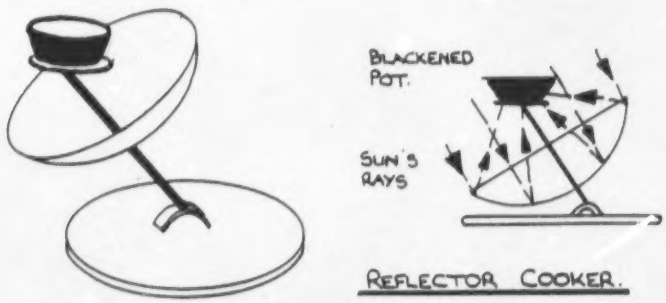
The meal to be cooked is placed in a metal liner with the outside blackened, in the centre of the oven. Two glass sheets with about 2 cm between them are placed on the top. The lid, which is vertical when used for cooking is lined with aluminium foil. This reflects the sun's rays into the oven through the double cover glass sheets. Since much of India lies near the equator and the sun is nearly overhead at midday, the ghosh oven does an excellent job of cooking the noon meal.




GHOSH - TYPE SOLAR OVEN.

## REFLECTOR TYPE SOLAR COOKER

The basic principle of the operation of reflector-type solar cooker is shown in the figure below, where a simple parabolic reflector, arranged on a sun-following mount, concentrates the sun's rays on a grill which can support a pot or frying pan. This type of cooker will become hot just as soon as it is adjusted to face the sun and according to experimental results, a 1 metre diameter reflector-type cooker will deliver the equivalent of a 400 watt electric plate under bright sunshine.




REFLECTOR COOKER.

## SOLAR FURNACES

Remembering that the surface of the sun has a temperature of 6000°C, it is fortunate that such heat does not reach the earth. The highest temperature so far on record is a mere 50°C in the shade. However, by concentrating the sun's rays on a smaller area, we can increase the temperature. With a magnifying glass enough heat can be generated to start a fire.

The solar furnace uses curved mirrors to focus the sun's heat and to obtain the maximum amount of heat the mirrors are paraboloid not spherical which gives the tiniest focal point.

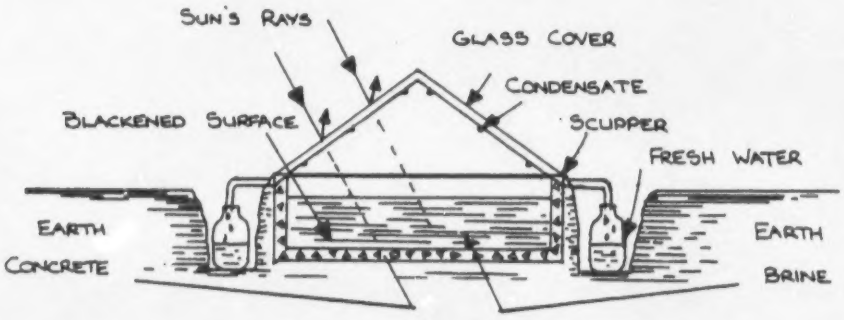
An accurately ground reflector produced a temperature of more than 3000°C and in some parts of the world have been used to produce metal from the ores.

## SOLAR STILLS AND SOLAR DRYERS

Probably the oldest intentional use of the sun's ability to produce heat came when primitive men allowed pools of salt water to evaporate to produce salt essential to the human diet. This process is still in use in many parts of the world.

## SOLAR DISTILLATION

Controlled evaporation to produce fresh portable water from salt or brackish sources is a much more recent development. Below is shown the general idea of these simple devices. A water-tight compartment, made of wood or concrete, is painted black to absorb the solar radiation which enters through the glass roof of the still. Salt or brackish water, or even sewage effluent, is allowed to flow into the channel or box to a depth of 60-100 cms. The incoming solar radiation heats the water, causing some of it to evaporate and this condenses on the inner surface of the glass roof.

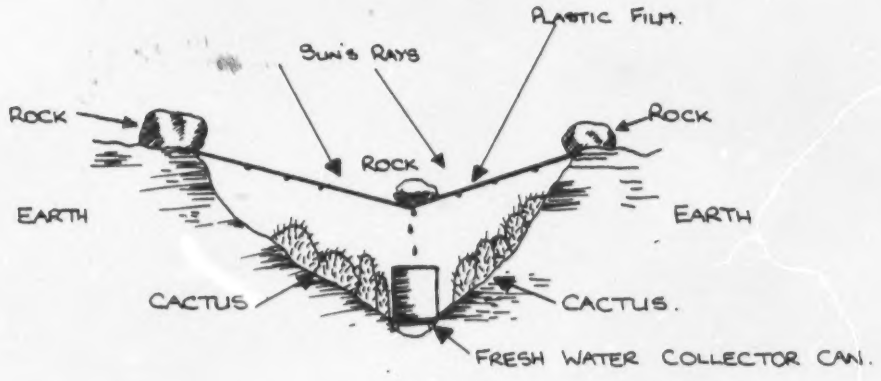



GLASS COVERED SOLAR STILL.

Since water will 'wet' clean glass, the condensation takes place in the form of a very thin film which flows down by gravity into the scupper which leads the condensate off to a suitable container. The water channel is insulated by the earth. After some of the water has been distilled off, the brine which is left is flushed out at intervals. This prevents the concentration of salt from building up to the point when it will cover the bottom of the still with reflective white crystals.

The product of such a still is distilled water which can be used for drinking, for filling storage batteries, or for any other purpose for which pure water is needed.

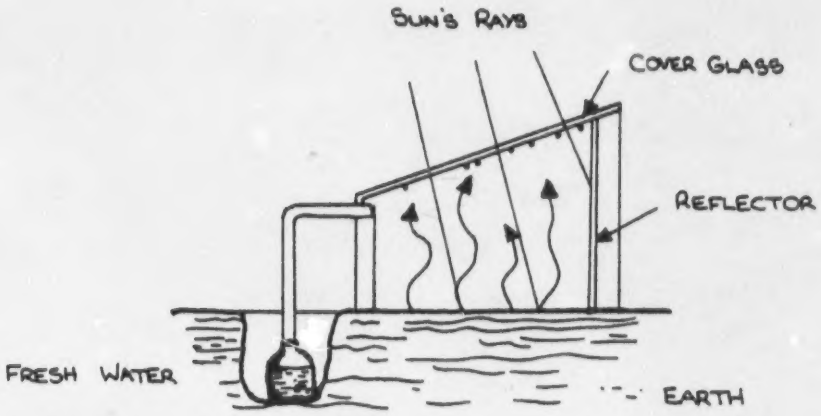
Below is shown a desert survival still. The kit includes only a sheet of transparent plastic and a tin can, since the other needed materials can be found in the desert. Even in the dryest earth there is always some moisture and it can be distilled out by creating a heat trap as shown below by using a transparent plastic cover, a rock to weigh the cover down in its centre and a can to catch the droplets of moisture as they trickle down the inner surface of the plastic. This is the desert version of the ocean rescue still which uses inflatable plastic bags which, in an emergency, can be used to make drinking water from ocean water.




DESERT SURVIVAL SOLAR STILL.

Dr. M. Kobayashi of Tokyo, proved that water can be extracted from virtually any kind of soil by the earth still shown below . He used a typical still construction, complete with cover glass and reflector to increase the amount of solar radiation reaching the earth. He has tested his still at the

top of Mount Fujiyama where the soil is volcanic ash and in the arid deserts of Pakistan, and he has never failed to produce water which is pure and palatable.




EARTH STILL.

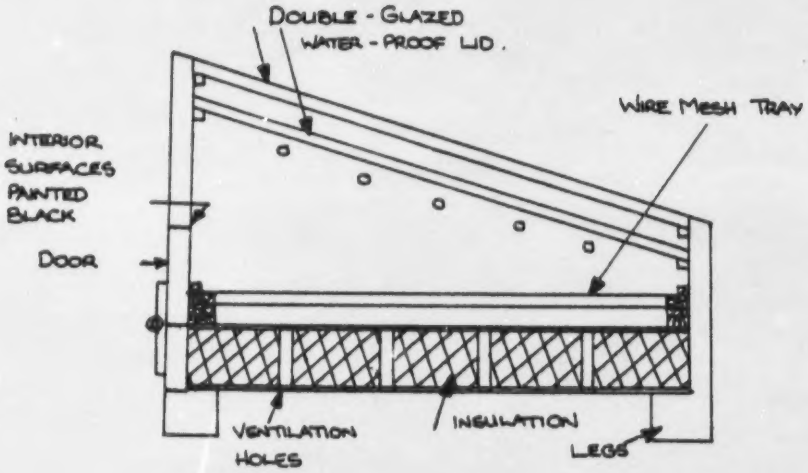
## SOLAR CROP DRYERS

Sunshine has been used since time immemorial for the purpose of drying crops. This has traditionally been accomplished by simply exposing the crop to the sun's rays and hoping that no rain would fall until the drying process has been completed. A more sophisticated technology has been evolved during the past two decades to make more effective use of the sun's thermal power and to minimize the usual contamination associated with natural dehydration. The most common sources of contamination are:-

a) airbone dust and wind-blown debris, such as leaves,
b) insect infested and presence of larvae, etc.,
c) animal and human interference.

To minimize contamination and to maximize the effectiveness of the sun's rays, it is essential that the drying area be covered by a transparent material.

The dryer is essentially a solar hot box, which can be used to dehydrate fruit, vegetables, fish, or any other product which needs to be dehydrated for preservation.



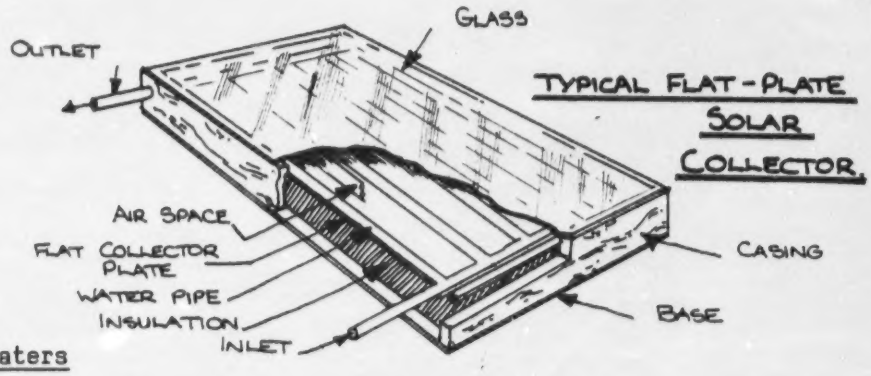

SECTION THROUGH TRAY-TYPE SOLAR DRYER.

## SOLAR WATER AND AIR HEATERS

The heating of water and air by solar radiation if one of the oldest and most valuble applications of helio thermal technology. The variety of water heaters and air heaters is almost endless and they all operate on much the same principle.

### Solar Water Heaters

A common solar water heater is one which uses a flat-plate grid collecter as shown below.



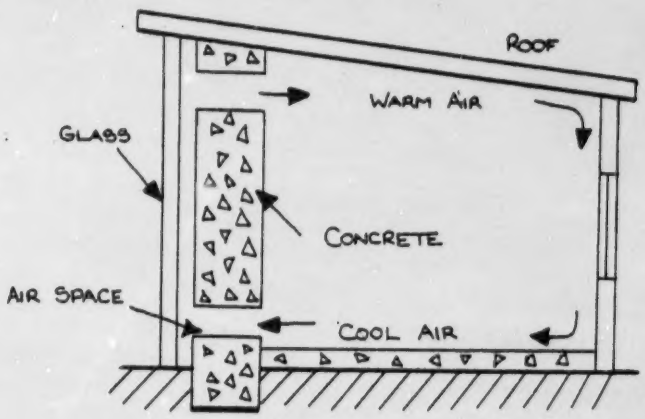

TYPICAL FLAT-PLATE SOLAR COLLECTOR.

### Solar Air Heaters

The same principle is used in a solar air heater as in a solar water heater, a darkened collector plate absorbs heat and a covering prevents the heat from escaping. The solar air heater is much less expensive because there is no need to worry about freezing, and any leakage which occurs will not cause the kind of damage which water can create. The drawback to our systems is the fact that fans are larger, more expensive and more power

consuming than the small pumps used with some solar water heating systems. Also, the ducts which are used to carry the air are much larger and more costly than pipes used with water systems.

The simplest of all solar air heaters,and one which is in increasingly wide use now, employs a heavy south facing, vertical, concrete wall (see below ) which is painted a dark colour and covered with a sheet of glass. An air space runs between the concrete and the glass, and the chimney effect causes the heated air to rise. Openings at the bottom and top of the wall allow the cold air along the floor to enter the air space and similar openings at the top provide an opportunity for the warm air to re-enter the room behind the wall. The air circulates through the room, warming the walls and the occupants. Small electric baseboard heaters are used to provide heat during long periods of bad weather.




TROMBE - TYPE SOLAR AIR HEATER.

Solar Cells

The use of solar cells or photovoltaic cells for producing electricity from the light of the sun have been used for a number of years in the space industry to power satellites. The electricity is produced when light energy strikes certain specially treated substances, such as, silicon, selenuim and copper oxide. The electrical power produced by each cell is very small. a 2 centimetre square silicon cell will give on average a short circuit current of 0.10 amperes or an open circuit voltage of 0.60 volts. To provide larger amounts of electricity many thousands of cells would have to be connected together. Enough cells could power a small television or as suggested in the exctract taken from the New Scientist, to power irrigation pumps.

At the present moment the solar cells are very expensive to produce but the cost is continuously coming down where at some time they will be comparable with the cost of the way we now produce electricity. Since most of the underdeveloped world lies on that part which receives the most sunlight

it has been suggested that some time in the future solar electricity power stations could be erected on the vast areas of waste desert land producing electricity from a free source.

## SOURCES OF INFORMATION FOR CONTRUCTING ENERGY CONVERTORS

1) Appropriate Technology - A school community kit published by Community Service Volunteers, 237 Pentonville Road, LONDON. N19 9NJ
Also available from: The Directory of Social Change, 14 Saltram Cresent, LONDON. W9 and Oxfam, 274 Banbury Road, OXFORD. OX2 7D2
This kit contains information on how to construct a windmill to produce elecricity from spare parts; a flat-plate absorber and the focussed array of the sun's energy; a simple slat-plate solar water heater and a laboratory construction of a methane digestor.

2) What is Appropriate Technology Jigsaw? - An Oxfam news and topic sheet. Simple explanation on how to construct a Persian water wheel.

3) Centre for Alternative Energy, Llwyn Gwern Quarry, Machynlleth, Powys, Wales. The centre publishes many useful information sheets on energy convertors.

4) Solar Energy Study Equipment - Design and Materials Ltd., - provide a full working kit and instructions of a solar powered water heater.

5) School Science Review - vol. 59 Number 209 June 1978 p.p. 634-644. Investigation and construction of a thermo syphoning solar hot water system as a school project.

6) School Science Review - vol. 60 number 213 June 1979 p.765. Suggests using a heat exchanger from discarded refrigerator as a solar collector.

7) Simple Working Models of Historic Machines - A.F. Burstall - Edward Arnold (Publishers) Ltd., LONDON. This book contains many ideas and instructions for making and putting to work models of scientific and historic significance.

## REFERENCES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2. Energy Primer - Portola Institute.
3. Science for the 70's - Richie,Mee and Boyd.
4. Science for the Elementary School Teacher - Gerald S. Craig.
5. Appropiate Technology - P.D. Dunn.
6. Development Studies - P. Jones, R. Morgan, R. Shipton-Smith, D. Wright - Extra Mural division, Shool of Oriental and African Studies, University of London.
7. Physics, Fundamentals and Frontiers - Strillberg & Hill - Arnold.
8. Simplified Wind Power Systems for Experiments - Jack Park available from IT publications.
9. Energy Primer - comprehensive sourcebook about renable forms of energy. Available from IT Publications.


For more information and publications - lists are available from:

Intermediate Technology Development Group,
9 King Street,
LONDON. WC 2

Centre for World Development Education,
128 Buckingham Palace Road,
LONDON. SW 1

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Writers: Natalie Jones, Wyn Hughes Typing: Marjorie Eccles
Graphics: Karen Moss

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